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SOCIETAL LIFE CYCLE ASSESSMENT

Potential hotspots identified by social LCA—part 1: a case study of a laptop computer

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Abstract
Purpose A generic hotspot assessment of social impacts from a product was conducted, using a laptop computer as a case. The aims of the case study were to identify social hotspots of the laptop and to test and evaluate the methodology.
Methods The case study was based on the social LCA methodology described in the Guidelines for social LCA and included the product system from 'cradle to grave' as well as the impacts on all relevant stakeholders. We focused on a simplified list of materials and used mainly country-specific data.
Results and discussion A new method for impact assessment of hotspots was developed. The total activity in each phase was distributed among countries. The countries were divided into groups related to the extent of activity in the product system, as well as to their performance on a subcategory. High values in both groups were highlighted and hotspots were identified.

The results revealed some hotspots, some hot countries and some hot issues, all indicating a risk of negative social impacts in the product system of a laptop. It also identified workers and the local community as the stakeholders most at risk of negative social impacts. Among the hotspots identified, the following subcategories were of importance: safe and healthy living conditions, social benefit/social security, access to material resources, involvement in areas with armed conflicts, community engagement (lack of), corruption, and access to immaterial resources.
Conclusions The study showed it is possible to conduct a social LCA on a generic complex product using the Guidelines, even though data collection was impaired by lack of data and low data quality. It identified methodological issues that need further attention, for example the indicator impact pathways. Still, it is clear that new insights can be gained by social LCA, where the life cycle perspective and the systematic approach help users identify potentially important aspects that could otherwise have been neglected.

Keywords Case study · Generic assessment · Hotspot · Impact assessment · Laptop computer · S-LCA · Social LCA · Social life cycle assessment

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Preamble We have conducted a case study of S-LCA on a generic laptop computer. The results of the study are presented in two related papers. This first paper, Part 1, presents the social hotspots of a generic laptop identified in our study. The second paper, Part 2, (Ekener-Petersen and Moberg 2012) discusses the usability and applicability of the methodology proposed in the Guidelines, based on our experiences from the study.

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1 Introduction

Computers are becoming a natural part of everyday life, at least in the industrialised world. In June 2008, the

number of personal computers in use worldwide hit one billion, while the two billion figure is expected to be reached by 2014 (Gartner Inc 2008). About 180 million computers (16 % of the existing installed base) were expected to be replaced and 35 million to be dumped into landfill in 2008 (ibid). Since 2008, more than half of all computers sold have been portable types, i.e. laptops (Meta Facts Inc 2009).

The increasing number of computers is often viewed as a positive development, as computer availability improves access to information and the possibilities for individuals to choose their own way of life. The World Summit on the Information Society (WISI) has identified the following benefits of ICT, which can also be supported by the use of a laptop computer:

1. Access to government services
2. Access to essential information on material, financial, legislative and other resources for businesses
3. Access to improved healthcare
4. Access to the labour market
5. Access to education
6. Access to improved farming methods
7. Access to enhanced knowledge of environmental issues
8. Access to exchanges in the scientific society

The magnitude of these benefits for the society is determined, among other things, by the design and production of the laptop to allow affordable access for all (WISI 2010).

However, there may also be a negative side to this positive picture. Some ethical dimensions, or risks, connected with the use of ICT were also identified by WISI. These were for example the abuse of private and personal data, the expression of racism, intolerance, xenophobia, violence and child abuse in the Information Society (ibid). Further, questions about possible negative social impacts in the supply chain for electronics have been raised, particularly for the supply chain in the developing world, where for example poverty and lack of legislation sometimes lead to unacceptable working conditions. This has been described by different reports by NGOs (Finnwatch and Swedwatch 2010; Resolve 2010; Friends of Nature, IPE & Green Beagle 2011). The ICT industry is working to address these concerns, for example through the Electronic Industry Citizenship Coalition (EICC) and the Global e-Sustainability Initiative (GeSI).

There are a number of tools available for analysing and assessing social impacts. In this paper we present a case study on a laptop computer, based on the methodology of S-LCA to assess the social and socio-economic impacts of products. This methodology is presented in detail in 'Guidelines for social life cycle assessment of products' (Benoît and Mazijn 2009; Benoît et al. 2010), hereafter called 'the Guidelines'. The aims of the study were to identify social hotspots in the product system of a generic laptop and to test and evaluate the methodology.

2 Methodology and methods

2.1 General

In the methodology described in the Guidelines, the social impacts are assessed in relation to stakeholders and/or impact categories. The Guidelines suggest five different stakeholder categories; Worker, Local community, Society, Consumer and Value chain actor. The Consumer stakeholder is only considered in situations of retailer interaction. Other impacts during the use phase of the product are not included.

Each stakeholder is associated with a number of subcategories (Benoît and Mazijn 2009, p. 49), including for example child labour, fair salary, health and safety, local employment, cultural heritage and corruption. Methodological sheets have been prepared in connection with the Guidelines (Benoît Norris et al. 2011) to support data collection by providing more information on subcategories and suggesting inventory indicators and data sources, mostly as internet addresses. There may be several indicators, and related data sources, proposed for each subcategory. The type of data suggested is a mix of qualitative, quantitative and semi-quantitative measurements from many different sources. The terms related to the Guidelines in this paper are used in the way they are defined there.

2.2 Scope and functional unit for the case study

The functional unit in the study was a laptop with generalised features and with a typical product system for such a computer. A laptop is interesting since it is a product that many people are familiar with, it is widely used and it has a complex supply chain that offers a good opportunity to fully test the Guidelines. The case study sought to include the product system from 'cradle to grave' and the impacts on all relevant stakeholders as suggested by the Guidelines. The laptop was assumed to be bought and used in Sweden.

The study did not include the social impact from electricity generation and other inputs of a supporting kind, nor did it include the social impacts related to transport. These activities also have social impacts, but are not covered within the framework of this study, where the main focus was on production processes more specific for the laptop.

In gathering data, we focused on country-specific data for the indicators and very little sector-specific information was inventoried. The data were collected from the sources suggested in the methodological sheets as described below.

3 Results

3.1 The product system

To describe the product system, the first step was to obtain knowledge of the supply chain and identify the raw materials used to make a laptop and the countries involved. A laptop computer consists of around 1,800–2,000 parts (Manhart and Grießhammer 2006) and the supply chain may include hundreds of different suppliers with different grades of vertical integration (EICC/BSR 2010). As the full supply chain of a laptop is very complex, it was simplified for this hotspot assessment case study by grouping the unit processes into the following production phases:

- Resource extraction
- Refining and processing of raw materials
- Manufacturing and assembly (including manufacturing of components, assembly of complex components and final assembly)
- Marketing and sales
- Use (i.e. customer relations)
- Recycling and disposal

3.1.1 Resource extraction

The main resources extracted to manufacture the laptop were identified by consulting a Bill of Materials (BOM) for the laptop (European Commission 2005, p 124). It was not possible to identify all raw materials, as in addition to specified materials the BOM also included a number of components where the constituent raw materials were not specified. A material balance presented by Hewlett-Packard (HP) in 2005 (Madeleine Bergrahm, HP, personal communication 2011) suggests the general distribution of materials in a laptop (Table 1).

These material categories can be further split into more specific materials. Data provided by GeSI companies suggest that a current generic personal computer assembly (including printed wire board, memory, and other electronic components such as chips and capacitors) is made up of more than 50 materials, of which 20 or more are metals (EICC/GeSI 2008, p 9). For the metals selected for study by EICC/GeSi, the generic personal computer is made up of approximately 12 % copper, 8 % tin, 1 % aluminium, 0.0084 % gold, and 0.0007 % palladium, with undetected amounts of cobalt (EICC/GeSi 2008 p. 9).

Based on the BOM and the sources mentioned above, in combination with other sources (Manhart and Grießhammer 2006, p. 24; Finnwatch and Swedwatch 2010, p.7), we decided to focus on the simplified list of materials presented in Table 2. The percentage for quartz sand was assumed to be 9 % based on the sources mentioned above, while that for crude oil was assumed to correspond to the percentage of plastic, i.e. 33 % (see Table 1).

The main countries supplying raw materials in the resource extraction phase were identified by global production data and are shown in Table 3.

3.1.2 Refining and processing

The refining and processing phase in the product system includes in this case smelters and refineries for minerals and refineries and chemical plants for the production of plastics from oil. According to global market data, the following countries are most important in one or more of the different processes: China, the USA, Thailand, Russia and Saudi Arabia, as well as Canada and Germany (EICC/GeSi 2008, p. 33; MadSci Network).

3.1.3 Manufacturing and assembly

Manufacturing and assembly is perhaps the most complex phase of all, making it almost impossible to map. It includes component manufacturers and production of motherboard, battery cells, display, optical drive, battery pack, and case. Assembly is done in several steps; assembly of complex components, assembly of the screen, components, and the final assembly of the chipset and main memory. However, China, Taiwan, Japan, South Korea, and the USA

Table 1 Relative distribution (% by weight) of materials in a laptop

Material	Relative proportion, % by weight
Plastics	33
Metals	25
Circuit board	20
Battery	11
Cables	6
LCD-panel	5

Table 2 Simplified list of raw materials and estimated relative proportions (% by weight) in a laptop

Raw materials		Estimated relative proportion, % by weight
Metal resources	Iron ore	13
	Copper ore	10.2
	Tin ore	8
	Bauxite (aluminium ore)	4
	Gold	0.0084
Quartz sand		9
Crude oil		33

Table 3 Main countries for raw material extraction

Raw material	Comment	Country of extraction	% of global extraction	Source
Tin	36 % of world production to the electronics industry	China	37	Resolve 2010, p. 7 ff
		Indonesia	31	Resolve 2010, p. 7 ff
		South America (Peru, Bolivia)	22	Resolve 2010, p. 7 ff, EICC/GeSi 2008 p. 31
		Democratic Republic of Congo (DRC)	5	Resolve 2010, p. 7 ff
Copper	Estimated less than 1 % used by the electronics industry.	Chile	35	EICC/GeSi 2008 p.13, 31
		North America	8	EICC/GeSi 2008p. 31
		Peru	7	EICC/GeSi 2008 p. 31
Aluminium	Estimated less than 1 % goes into electronic components and products	Australia	35	EICC/GeSi 2008 p.11, 26
		Brazil	12	EICC/GeSi 2008 p. 11, 26
		China	12	EICC/GeSi 2008 p.11, 26
Gold	In 2007, the electronics industry accounted for 9 % of the global demand for gold	China, South Africa, United States, Australia	40 all together	EICC/GeSi 2008 p. 13, 30
Quartz sand (lascas, quartz crystal)	Abundant in the Earth's crust	Canada, Brazil, Germany and Madagascar for lascas, USA and Brazil for quartz crystal	Major suppliers	Rajasthan Mineral
Crude oil	Used for production of plastic	Russia	12	US EIA
		Saudi Arabia	12	US EIA
		United States	11	US EIA
Iron ore		Brazil	26	Ecoinvent
		China	25	Ecoinvent
		Australia	17	Ecoinvent

are mentioned in the literature as the countries' most involved, followed by the UK, Malaysia, Singapore, and Hong Kong (Manhart and Grießhammer 2006, p. 27; Resolve 2010).

3.1.4 Marketing and sales, use

The marketing and sales phase and the use phase, i.e. the interaction between user and producer, were assumed to take place only in Sweden.

3.1.5 Recycling and disposal

The final phase is recycling and disposal. We did not consider reuse of the laptop. EU legislation restricts the export of e-waste unless it is proved that it meets the requirements stated in the WEEE Directive (WEEE 2002), and there is a total ban on exporting it to non-OECD countries (Basel Convention 1989). Recycling and disposal is hence normally done in the country of the end-user, in this case Sweden, with only a small flow of e-waste treated in other EU countries such as Germany, Poland, and the UK (Naturvårdsverket 2009). However, it has been shown that part of the e-waste from the EU ends up being illegally exported to developing countries (UNODC 2009). The amount of e-waste transported from industrialised to developing countries, mainly Nigeria and Ghana in West Africa, is an estimated 94,900 tons per annum (ibid.). As the EU generates 8.7 million tons of e-waste per year (ibid), an assumption that 75 % of the flow originates from the EU leads to the conclusion that less than 1 % of the e-waste generated in the EU is being illegally exported to developing countries.

Overview of product system All together, 32 different countries are involved to different degrees in the product system of the generic laptop described here and were therefore investigated. A picture of the simplified product system is presented in Fig. 1.

3.2 Life cycle inventory

Since this was a generic study, we mainly collected national data. The need for data was defined first by identifying the countries' most involved in each phase. The countries to

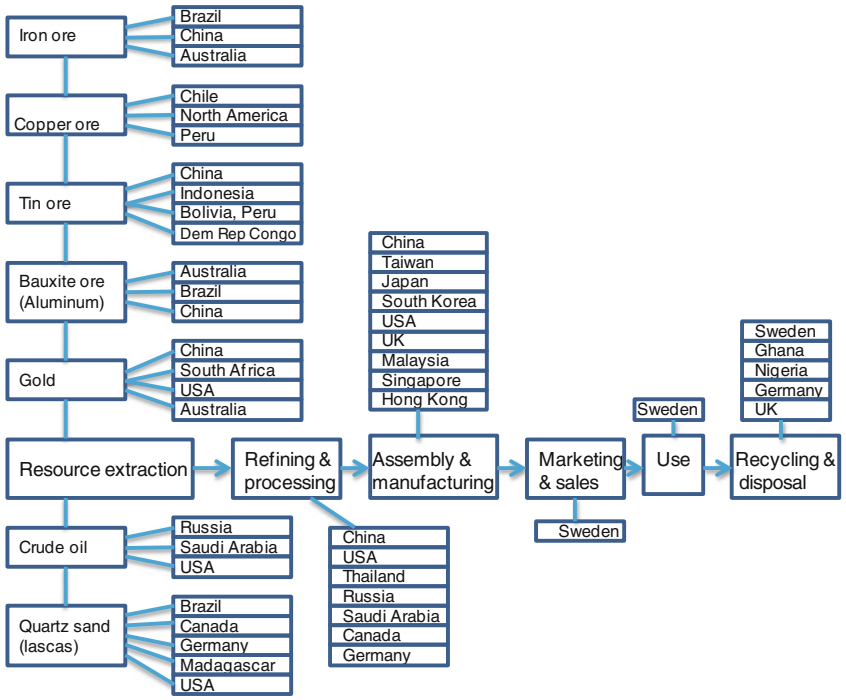

Fig. 1 Simplified product system for a generic laptop

investigate were identified when designing the product system, see above.

In the next step, the stakeholder and related subcategories assumed to be most affected in each phase were identified. This was done based on a judgment on the type of activities in each phase and the impact on stakeholders from these activities. The result was that most of the subcategories included were listed for each phase (Table 4).

In this hotspot identification, we thus did not investigate all the countries that might be involved, only those in our simplified product system, nor all the subcategories that might be affected in each phase, only those deemed most affected.

Data were then collected using the data sources suggested in the methodological sheets. We collected country-specific data for the identified combination of country and subcategory for each phase. If available at the designated source, we collected sector-specific data as well. However, such data were only available for workers' hours (International Trade Union Confederation, ITUC).

The result was a mix of country-specific data in different formats for the most relevant social impacts along the product system, entered into a spreadsheet (see Fig. 2). The data collection process was impaired by a lack of data and sometimes low data quality. For example, data for all relevant countries were not always found in the proposed sources, i.e., the data collection was not complete. In some cases, the suggested data source did not contain any relevant data (any longer). Out of 54 proposed indicators, some of them even with multiple data sources, 25 were invalid or not relevant. Table 5 lists the data found—or not found—at the respective source.

Due to the lack of data and with the ambition to obtain data for as many countries as possible, we decided to accept data from different years in the same dataset, as well as quite old data. However, we limited data collection to data from the year 2000 onwards.

Occasionally, the data collected from the data source were not directly comparable between the different countries, e.g., due to the size of a population. An example is 'number of displaced persons', which seemed more relevant to use after relating it to the size of the population.

Sometimes data were expressed per region or per continent in the data sources. In these cases, countries were linked to a region/continent and attributed data. The differentiation among countries was of course less for those indicators. We did not search for additional data outside the sources proposed in the methodological sheets.

3.3 Defining country significance in each phase of the product system

The data collected initially related to the countries where the activities in the product system are generally performed. However, the data in an LCA should be related to the specific product assessed, and different countries have different levels of activity in the product system of the laptop. To determine this activity level, the total activity in one phase (or process) had to be distributed among all countries involved in that phase (or process). Hence, data were collected on each country's share of the total global activity in the extraction of resources, the supply of assembly services and the other activities performed in the product

Table 4 Stakeholders, subcategories, and phases examined in the study

Stakeholder	Subcategory	Resource extraction	Refining and processing	Manufacturing and assembly	Marketing and sales	Use	Recycling and disposal
Worker	Freedom of association; Collective bargaining	x	x	x	X		x
	Child labour	X		x			x
	Fair salary	x	x	x	x		x
	Working hours	x	x	x	x		x
	Forced labour	x	x	x			x
	Equal opportunities /discrimination	x	x	x	x		x
	Health and safety	x	x	x			x
	Social benefits/social security	x	x	x	x		x
Consumer	Health and safety				x	x	
	Feedback mechanism				x	x	
	Consumer privacy				x	x	
	Transparency				x		
	End of life responsibility				x	x	x
Local community	Access to material resources	x	x	x			x
	Access to immaterial resources	x	x	x	x		x
	Delocalisation; Migration	x	x	x			x
	Cultural heritage	x	x	x			x
	Safe and healthy living conditions	x	x	x	x		x
	Respect for indigenous rights	x	x	x			x
	Community engagement	x	x	x	x		x
	Local employment	x	x	x	x		x
	Secure living conditions	x	x	x			x
Society	Public commitment to sustainability issues	x	x	x	x		x
	Contribution to economic development	x	x	x	x		x
	Prevention and mitigation of armed conflicts	x	x	x	x		x
	Technology development	x	x	x			x
	Corruption	x	x	x	x		x
Value chain actors	Fair competition	x	x	x	x		x
	Promoting social responsibility	x	x	x	x		x
	Supplier relationships	x	x	x	x		x
	Respect for intellectual property rights	x	x	x	x		x

system (Ecoinvent 2009; US EIA; EICC/GeSi 2008; Wikipedia; Rajasthan Mineral), and the activity percentage for each country in each phase was calculated.

The result was a ranking of countries regarding their total activity in the respective phases in the product system of the laptop. The rankings were then grouped into four categories—very large activity (pink/dark), large activity (blue/medium), moderate activity (yellow/light), and other countries. The three most active (colour-coded) groups of countries per phase are displayed in Tables 6, 7, and 8. These tables and the assessments behind them are described below for each phase.

3.3.1 Resource extraction

For resource extraction, more advanced calculations had to be made. As this phase covers many different metals and other resources, all with different extraction patterns, an assessment had to be made of the contribution of each resource to the laptop. We chose to use the weight of each material in the final laptop as the basis for calculating the activity in this phase, as exemplified by calculations for the resource extraction phase. As shown in Table 1, plastics based on oil account for approximately 33 % of the

Stakeholder	Subcategory	Indicator	Unit of measure	China	Thailand	US	Saudi Arabia	Germany	Source	Worldmax and min of indicator	Mean and limit for the 25% highest (lowest) values
Worker	Equal opportunities /Discrimination	Women in Labour force	Female working percentage as % of male working percentage	88	83	85	27	87	The World Bank, CPIA	max 100; min 12	56 and 34
	Social Benefits/Social Security	Social Security Expenditure	Spending as % GDP	5.33	4.74	14.79	0.21	26.17	ILO	max 29.40; min 0.08	7.41 and 14.74
Local community	Access to material resources	Changes in Land Ownership	Publicly owned forests %	68	88	43	98	53	FAO Global Forest Resource Assessm 2010	max 100; min 0	25 and 50
		Levels of Industrial Water Use	Annual freshwater withdrawal by industry, % of	25.7	2.5	46	3	67.9	World Bank, Water Resource Management	max 85; min 0	42.5 and 63.75

Fig. 2 Section of the spreadsheet (adapted, for illustrative purposes only)

materials in a laptop. Looking at global statistics for oil extraction, we found that Russia, Saudi Arabia, and the USA are the top three largest producers, with Russia extracting 12 % of world production (Table 3). We then multiplied the percentage of world extraction by the relative percentage of that specific raw material, here oil, in the materials balance for the laptop. Hence, for Russia, 0.33 was multiplied by 0.12, giving 0.04. This means that according to this calculation method, Russia carries out 4 % of the activity in the phase. However, this is only true if oil is the only resource extracted in Russia. If other relevant resources are extracted there, the relative proportions of those resources in the materials in the laptop must be multiplied by the corresponding Russian share of world production. For example, Russia is also involved in the extraction of aluminium. In this case, Russia is extracting 7 % of the world production, and aluminium constitutes about 4 % of the laptop content (Table 2). Hence, 0.07 multiplied by 0.04 gives 0.0028. The activity in the phase related to aluminium is thus 0.28 %. The Russian share of the activity in the resource extraction phase is then 4 % (for oil)+0.28 % (for aluminium)=4.28 %. This calculation exercise is repeated for all the raw materials in the laptop where the specific country, in our case, Russia, is involved in extracting activity, adding additional percentages to the 4.28 % we have so far. By adding the percentages of activity calculated for each extracted material for a country, the percentage of the total extracting activity for that country in that phase is determined. In our case, Russia is also involved in the extraction of gold, ending up with 4.40 % of total extraction activity.

We found that two countries—Brazil and China—carried out the largest activity in this phase (Table 6). We classified these as countries with very large activity, followed by Russia, USA, Saudi Arabia, Bolivia, and Australia as countries with large activity and Canada, Chile, and Indonesia as countries with moderate activity.

3.3.2 Refining and processing

In the refining and processing phase a number of processing steps are involved, differing between metals and plastics. This phase was assumed to be divided into one third for metal refining and processing, and two thirds for plastics, as plastic production is seen as having more process steps involved. The activity of the countries involved in each process (US EIA; Plastics Europe 2010) was then multiplied by this fraction.

The calculations identified China and the USA as having the largest activity in this phase (see Table 7), so they were classified as countries with very large activity. Saudi Arabia, Thailand, and Russia were classified as countries with large activity and Canada and Germany as countries with moderate activity.

3.3.3 Manufacturing and assembly

This phase is very complex and it was not possible to get reliable quantitative data on the distribution of activity among the different countries involved in the manufacturing and assembly of components into the final laptop. However, we used some indicative data from the literature (see the description of the product system above) to estimate the grouping in this phase (see Table 8)

3.3.4 Use; recycling and disposal

For the remaining phases, Sweden dominated the activity and no grouping was made. The grouping of countries as described above was used in the impact assessment to identify hotspots.

Table 5 Data sources and indicators for different subcategories as cited in the methodological sheets and availability of data

Data source	Related subcategories	Indicators	Data y/n	Comment
COHRE Global Survey on Forced Eviction	Delocalisation and migration	Forced evictions	y	Lack of data for several countries involved
US Dept. of State, Country Reports on Human Rights Practices	Delocalisation and migration	Internally displaced persons	y	Lack of data for several countries involved
	Community engagement	Peaceful assembly and association	y	
	Respect for indigenous rights	Indigenous land rights conflicts/claims	n	
	Hours of work	Excessive Hours of Work	n	Mostly about law enforcement
UN International Migrant Stock	Delocalisation and migration	International migrants	y	Unclear causal pathway
World Economic Forum	Community engagement	Transparency of government policymaking	y	Based on surveys of the business sector
	Community engagement	Public trust in politicians	y	Based on surveys of the business sector
	Local employment	Presence of local supply network	y	Based on surveys of the business sector
	Access to immaterial resources	Levels of technology transfer	y	Based on surveys of the business sector
	Secure living conditions	Reliability of the police services	y	Based on surveys to the business sector
UNESCO Urgent Safeguarding List	Cultural heritage	Cultural heritage in urgent need of safeguarding	y	
Business and Human Rights Resource Centre	Cultural heritage, respect for indigenous rights	Prevalence of racial discrimination	y	Data on company actions of discrimination
Amnesty International Human Rights reports	Respect for indigenous rights	Human rights issues faced by indigenous people	y	Lack of data for several involved countries
	Access to immaterial resources	Freedom of expression	y	
	Secure living conditions	Security and human rights	n	
ILO data on unemployment	Local employment	Unemployment statistics Poverty and working poverty	y	
WIPO World Intellectual Property Organization	Access to immaterial resources	Patent filing	y	
	Respect for intellectual property rights	Patent filing IP related to respect for cultural heritage	y	The pathway is not evident
FAO Food and Agriculture Organization	Access to material resources	Changes in land ownership	y	
World Bank, Water	Access to material resources	Levels of industrial water use	y	Not related to availability/ scarcity of water
World Bank, Sanitation	Access to material resources	Access to improved sanitation facilities	y	
World Bank, Pollution	Safe and healthy living conditions	Pollution levels	y	A limit value related to health effects exists in Swedish legislation
OECD	Access to material resources	Extraction of material resources	y/n	

Table 5 (continued)

Data source	Related subcategories	Indicators	Data y/n	Comment
				Not used—unclear what figures to use
WHO	Safe and healthy living conditions	Burden of disease (DALY)	y	
World bank/Doing Business	Safe and healthy living conditions	Strength of laws on construction safety	y	Unclear pathway, many rules can indicate bureaucracy and not safety thinking
International Trade Union Confederation ITUC	Freedom of association and collective bargaining	Evidence of restriction	y	
	Hours of work	Excessive hours of work	y	Acceptable levels unclear
LabourStart	Freedom of association and collective bargaining	Evidence of non-respect or support	y	Unclear pathway
GRI Organizations Sustainability Reports	Freedom of association and collective bargaining	GRI HR5 Identification of operations where there is a risk	n	Not useful on a generic level—no compilation of individual values available
	Child labour	GRI HR6 Identification of operations where there is a risk	n	Not useful on a generic level—no compilation of individual values available
	Forced labour	GRI HR7 Identification of operations where there is a risk	n	Not useful on a generic level—no compilation of individual values available
	Social benefit/social security	GRI LA3 Identification of operations where social benefits are unevenly supplied	n	Not useful on a generic level—no compilation of individual values available
	Health and safety (Consumer)	GRI PR2 Incidents of non-compliance with regulation and voluntary codes	n	Not useful on a generic level—no compilation of individual values available
UCW Understanding Children's Work	Child labour	Percentage of children working	y	
Living wage calculator	Fair salary	Living wage in the US	y/n	Not useful only US data
Wikipedia	Fair salary	Minimum wage	y	Not useful as not related to living wage
Sweatfree	Fair salary	Non-poverty wages	y	Not useful as not related to living wage
US Dept of Labour	Forced labour	Commodities with high risk	n	
ILO, The cost of Coercion	Forced labour	Estimated percentage of forced labour	y	Data per region
World Bank, Gender Stats	Equal opportunities/dis-crimination	Woman in the labour force participation	y	
OECD Social institutions and Gender Index SIGI	Equal opportunities/dis-crimination	Gender Index ranking	y	
European Union OSHA	Health and safety (Worker)	Occupational accident rate	y	Data per region
ILO Social Expenditure Database	Social benefit/social security	Social benefit expenditure	y	
National governments	Public commitment to sustainability issues	Obligation on public sustainability reporting	n	No compiled data available
Sector reports			n	No compiled data available

Table 5 (continued)

Data source	Related subcategories	Indicators	Data y/n	Comment
	Public commitment to sustainability issues	Engagement of the sector regarding sustainability		
	Technology development	Sector efforts; R& D costs	n	No compiled data available
	Fair competition	Sector regulation and agreement	n	No compiled data available
	Promoting social responsibility	Code of conduct	n	No compiled data available
	Transparency	Transparency rating	n	No compiled data available
Heidelberg Institute for International Conflict Research	Prevention and mitigation of armed conflicts	Ongoing conflicts in the region; Business linkage to conflicts (e.g. resource extraction); Business linkage to escalation of conflicts (e.g. by pollution) or de-escalation (e.g. trade)	y	
Statistics about economic development (not specified)	Contribution to economic development	Economic situation	n	No compiled data available
National statistics	Contribution to economic development	Relevance of considered sector	n	No compiled data available
	Transparency	Presence of law or norm	n	No compiled data available
Transparency International	Corruption	Risk of corruption	y	
		Risk of corruption in sector	n	
US Dept of Health and Human Services	Health and safety (Consumer)	Quality or number of signs /information on products	n	Not useful, only US
US Consumer Product Safety Commission	Health and safety (Consumer)	Consumer complaints	n	Not useful, only US
Consumer Focus Western Australia	Feedback mechanism	Presence of mechanism; Number of customer complaints	n	Not useful, only US
Privacy International	Privacy	Ranking related to regulation on data-sharing; strength of laws on protecting privacy; regulatory powers to investigate	y	
Ecolex	End-of-life responsibility	Strength of legislation	n	No compiled data available
Global Competition Forum	Fair competition	National laws and regulations on competition	n	No compiled data available
Consumer International	Fair competition	Sector is present in consumer unions	n	No compiled data available

Table 6 Activity in different countries for a laptop: Resource extraction phase

Country	Activity, %
Brazil	12.1
China	10.2
Bolivia	6.4
US	4.6
Russia	4.4
Australia	4.3
Saudi Arabia	4.0
Chile	3.6
Indonesia	3.5
Canada	3.2

3.4 Defining the significance of phases in the product system—the activity variable

To obtain information about hotspots considering the whole product system, we also needed to calculate the relative magnitude of the activity in each phase by using an activity variable. We chose workers' hours; one of the activity variables suggested in the Guidelines.

However, due to lack of data we were not able to calculate the activity variable in our case study. Instead, we made some indicative estimations of the relative importance of the different phases, displayed in Table 9. One of the estimations was made on the basis of the relative proportions of materials/components in the final laptop, assuming weight of the materials/components to be proportional to the number of workers' hours where these materials are handled. The second estimation was based on assessed attributes of the processes in each phase, such as the complexity and degree of automation of the process. These two estimations put the bulk of activity in the first three phases, with recycling and disposal also notable. In the third estimation, we made an assessment of the value added in each phase, giving slightly more emphasis to the marketing and sales phase. The three estimations of the relative activity in each phase showed similarities and for each phase we calculated a mean of the three estimations. The result, which is the estimated percentage that each phase represents of the supply chain, is shown in Table 9. It should be noted here that the use phase only includes customer relations aspects, in accordance with the methodology in the Guidelines, resulting in a low share of the activity.

We concluded that this estimation of the activity variable was the best option we had for defining the significance of the phases in the product system. However, it was only used in the discussion of the results, due to the great uncertainty.

Table 7 Activity in different countries for a laptop: Refining and processing phase

Country	Activity, %
China	28
US	19
Saudi Arabia	9
Thailand	8
Russia	8
Canada	5
Germany	2

Table 8 Activity in different countries for a laptop: Manufacturing and assembly phase

Country	Activity
China	Very large
Taiwan	Large
Japan	Large
South Korea	Large
US	Large
UK	Moderate
Malaysia	Moderate
Singapore	Moderate
Hong Kong	Moderate

3.5 Impact assessment

No particular impact assessment method is proposed in the Guidelines. In this study, we developed a new approach to impact assessment for hotspot identification.

The hotspots were identified here by combining two actions in the data collection spreadsheet (part of the spreadsheet is shown for illustrative purposes in Fig. 2). Firstly, we divided the countries into groups with very large activity, large activity, moderate activity, a process described earlier. This is the vertical orientation in the spreadsheet used and indicates the countries with most stakeholders potentially affected. Secondly, we highlighted the countries with values in the high end of the range of possible values for each specific indicator, a horizontal orientation in the spreadsheet used. To do this, we identified the world minimum and maximum values on the indicator, then picked out the countries with values in the highest quartile in the range, indicating severe impacts, as well as the countries with values in the second highest quartile in the range, indicating quite severe impacts. Where the strongest vertical and horizontal highlights coincided, we had a hotspot. We also marked all the spots where there were no data available with a dotted red circle, in order to detect any country with low availability of data, thereby escaping a potential identification as a hotspot.

Some subcategories were assessed by two or three indicators, others by only one. However, all indicators for a subcategory aimed to assess the same impact for that subcategory and should thus only be counted as one impact. To avoid certain subcategories prevailing in the final result, we summarised the scores for any subcategory having more

Table 9 Activity in different phases based on different criteria

Criterion	Resource extraction	Refining and processing	Manufacturing and assembly	Marketing and sales	Use	Recycling and disposal
Material weight	30	30	30	1	1	8
Phase character	33	20	35	1	1	10
Value added	20	20	40	9	1	10
Mean	28	23	35	4	1	9

than one indicator into one score. In this, we chose the most severe score if the indicators scored differently in one and the same subcategory.

3.6 Identified hotspots

The result of the hotspot identification can be displayed in various ways. Table 10 shows the countries with the potentially most severe social impacts in the product system of a laptop. The selection was made on different grounds depending on their activity, where severe total potential impact for a country was determined to be:

- Indications of severe impacts on four or more subcategories for countries with very large activity in the product system
- Indications of severe impacts on five or more subcategories for countries with large activity in the product system
- Indications of severe impacts on six or more subcategories for countries with moderate activity in the product system
- Indications of severe impacts on eight or more subcategories for all other countries in the product system

Another use of the results can be seen in Table 11, which shows the group of subcategories associated with the largest number of severe impacts.

The hotspots identified are displayed in Table 12. These are the spots where we found potentially severe impacts in very large activity countries.

The full spreadsheet, with the total result in more detail, is available in Online Resource 1–6.

3.7 Considering the results with respect to the activity variable

According to the rough estimation of the activity variable, the most influential phases in the product system investigated were resource extraction, refining and processing, and manufacturing and assembly. The recycling and disposal phase also had some influence, whereas the marketing and sales and use phases were relatively insignificant. In this particular assessment, the hotspots, as well as the 'hot' countries identified before considering the distribution of activity among phases, all occurred precisely in the three phases considered most significant in the product system. Consequently, the use of the activity variable to refine the results in this case had no modifying effect, only a reinforcing effect. As the data on the distribution of activity along the product system in our case study were unavailable, no firm conclusions can hence be drawn from these rough estimates.

4 Discussion

The study presented here is fairly unique. There are only a few examples of studies where the new social LCA Guidelines have been used and tested (e.g. Franze and Ciroth 2011; Macombe et al 2011; Reitinger et al. 2011). The product under scrutiny was also complex, involving more materials and production systems than most earlier studies. It was also a generic study, performed without information about any specific supply chain, thus testing the availability of generic information.

Table 10 Countries with the potentially most severe social impacts in the life cycle of a laptop in this study

Countries with very large activity and severe impacts	Countries with large activity and severe impacts	Countries with moderate activity and severe impacts	Other countries with severe impacts
China	Bolivia	Indonesia	Madagascar
Brazil	Saudi Arabia		Ethiopia
	Russia		Dem. Rep. of Congo
	Thailand		Mexico

Table 11 Subcategories most often associated with severe impacts

Subcategory	% of assessed countries having severe impacts	Stakeholder
Safe and healthy living conditions	66	Local community
Social benefit/social security	47	Worker
Access to material resources	44	Local community
Involvement in areas with armed conflicts	38	Society
Community engagement (lack of)	38	Local community
Corruption	31	Society
Access to immaterial resources	31	Local community

It is clear that in order to make the study feasible, several simplifications had to be made. In this study, for example, the focus was on some major raw materials, the product system was simplified and energy sources were not included. We believe that in the future, when more data become available, more complete studies will be possible.

Despite the complex product and problems in finding data, we were able to perform a case study. This led to a number of reflections on the methodology which is presented in the accompanying paper (Ekener-Petersen and Moberg 2012). Here we focus on the results of the case study and whether they are reasonable.

The results revealed some hotspots, some hot countries, and some hot issues, all indicating a risk of negative social impacts in the product system of a laptop. It also identified workers and the local community as the stakeholders most at risk of negative social impacts. However, this may partly depend on the design of the study, as the marketing and sales and use phases were performed in a European country.

It is difficult to evaluate a methodology when there is no absolutely true answer available with which to compare. Therefore we cannot assess whether the methodology gives the "correct answer". This is because we cannot empirically study the social (or environmental impacts) of a single product. Instead, we must rely on models that can connect impacts to the products studied (Heijungs 1998). When developing models, we must make methodological choices that are sometimes purely technical, but sometimes include value choices, the correctness of which we cannot determine (Finnveden 2000; Hofstetter 1998; Tukker 1998). However, we can study the methods and determine whether they contain any logical errors. We can also assess whether methods and data are compatible with the best scientific standards and we can analyse the results and see whether they seem reasonable or not (Ahlroth and Finnveden 2011). For example, we can compare the results of this study with what has previously been regarded as important social problems related to ICT products.

During recent years, several issues related to social conditions in the production and waste management of ICT products have caught the attention of the media. Examples include working conditions in factories in China, conflict minerals in DRC and hazardous treatment of illegal e-waste in West Africa (Finnwatch and Swedwatch 2010; Måwe 2010; SACOM 2011; Friends of Nature, IPE & Green Beagle 2011).

In the study presented here, working conditions in China was partly identified as a potential hotspot. China was singled out as a country with potentially severe impacts, but workers' conditions, often with long working hours and low wages, were not specifically captured, except perhaps in the subcategory 'Freedom of association and collective bargaining'. Analysing this outcome, our conclusion is that the reason why the working hours and wages in China did not show up as a hot issue in the study was lack of data. We were unable to find data on the wages in specific sectors in China that we could compare with the living wage. This issue would probably be easier to assess in a site-specific study, where data on the actual wages at some of the plants may be available. To assess this in a generic study, there is a need for data on a sector level. The same goes for working hours, where we could not find any data either.

When it comes to the extraction of conflict minerals in DRC, this issue was captured, but perhaps not as strongly as was expected. DRC was identified as a hot country—a country with potentially severe impacts but with limited activity. Involvement in areas with ongoing conflict was captured as a hot issue. However, the hotspot 'involvement in ongoing conflict in DRC' was not captured. One reason for this is probably that the activity in DRC was estimated to be relatively low, which in turn may depend on the fact that conflict minerals do not make up a very large proportion of the material content in a laptop. The issue may be more relevant for smaller devices, such as mobile phones. Moreover, the activity in this study was related to the weight of the material in the laptop itself. Other measures of the material could also be chosen, such as the value of different materials in the product, or the weight of the raw material that is extracted from the Earth. If the weight of the material

extracted from the Earth were used as a basis, the weight of the overburden and other parts of the ore would be included for metals, which would significantly increase the weight of gold and copper, for example.

The issue of illegally exported e-waste treatment was not very well captured in the assessment. The countries in question did not show up at all among the hot countries. The most notable issue around e-waste handling seem to be the health and safety of workers (Måwe 2010). In this assessment, the framing of the case study may have influenced the outcome, as the laptop was assumed to be used in Sweden. The flow of illegally exported e-waste from Sweden was roughly calculated to be less than 1 %, implying that the activity in developing countries in the recycling and disposal phase is very low.

Looking at the potential hotspots that the analysis did identify (see Table 12), it is interesting to note that both expected and somewhat unexpected results appeared.

The potentially most important stakeholder groups were workers and local community, which was perhaps to be expected. For workers, the issues of social benefits/social security, working hours and freedom of association emerged as important issues. The local community was mostly affected regarding access to immaterial resources, safe and healthy living conditions, community engagement, delocalisation and migration, cultural heritage, and respect for indigenous rights.

The countries showing up as potentially important were perhaps partly unexpected. For example, Russia, Saudi Arabia, Thailand, and Brazil are not so often discussed in relation to ICT products. In the case of Brazil, the reason is that Brazil is responsible for a large proportion of resource extraction (12.1 %), based mainly on its activity in tin and iron extraction, representing 6.4 % and 3.4 %, respectively, of total extraction for the laptop. This illustrates the added value of the life cycle perspective, where aspects related to important materials many tiers away in the supplier chain can be identified.

Among hot issues, a safe and healthy living condition was in the top position. Looking into this matter, we found that one indicator measuring this issue can be questioned. The number of rules and regulations involved when building a warehouse can be interpreted in a way that 'many rules mean a safer warehouse'. However, there may also be other interpretations, such as 'many rules implying a country with a heavy bureaucracy'. Many rules may even lay the foundation for corruption, thus implying a negative social impact. As this specific indicator was the reason behind the very negative result for this issue, its identification as a top priority problem may be incorrect. This illustrates the strong need for further development and improvement of the indicators in the Methodological sheets, to reduce the uncertainty of the results.

There are earlier studies on the social impacts of laptops to which our results can be compared. The most recent of these is by Ciroth and Franze (2011). Their study had a slightly different layout, as they made a specific assessment of a named laptop. In addition, they developed their own impact assessment method, differing from ours. However, a comparison of the results shows that they are quite similar. They have identified workers as the most affected stakeholder, followed by local community and society. Furthermore, they have found mining to be most connected to serious societal problems, but also informal recycling. The latter is a difference compared with our study, where informal recycling was not found to be among the hotspots. It could be interesting to investigate the reason behind this difference in future research. Another previous study is that by Manhart and Grießhammer (2006). However, it was limited to the production of laptops, excluding for example resource extraction and waste, and only looked at China. Thus, the scope of that study was more limited and it is difficult to compare the outcomes.

A criticism of the S-LCA concept is sometimes that it will not reveal any new information—the stakeholders already have knowledge of the social impacts from

Table 12 Identified potential social hotspots in the lifecycle of a laptop

Stakeholder	Subcategory	Countries involved with potentially severe impacts
Worker	Social benefits/social security	China, Russia, Saudi Arabia, Thailand
	Working hours	Brazil, Bolivia, Thailand
	Freedom of association and collective bargaining	China, Thailand
Local community	Access to immaterial resources	China, Bolivia, Russia, Saudi Arabia
	Safe and healthy living conditions	China, Saudi Arabia, Thailand
	Community engagement	China, Saudi Arabia, Brazil, Bolivia, Thailand
	Delocalisation and migration	China, Brazil
	Cultural heritage	China
	Respect for indigenous rights	Brazil

Table 13 Expected social impacts in the study according to individuals in the external reference group

Person 1	Person 2	Person 3
Resource extraction in Africa	Extraction of conflict minerals	Working conditions in resource extraction
Resource extraction in China	Working conditions in resource extraction	Impacts on society of resource extraction
Recycling in Africa	Working conditions in component manufacturing in China	Impact on local community of recycling and disposal
Recycling in Bangladesh	Manufacturing and assembly in China	Health and safety in recycling and disposal
	Working conditions in recycling in Nigeria	

products. To investigate this statement, at the beginning of the project we asked people in an external reference group to list their ideas on what we were going to find. The answers were written down and kept in a sealed envelope until the end of the project, when we compared them against our findings. The expected outcomes in the envelope are shown in Table 13.

Thus the general expectations were that the most severe impacts would be found in resource extraction and recycling and disposal. Moreover, the impacts on workers were perceived as the most problematic. Finally, China and Africa was targeted as the most problematic areas. Thus there were some differences compared with the actual results obtained in our case study (Table 14).

As shown by this comparison, the impact on the local community was underestimated by the reference group compared with the case study results. Furthermore, China was heavily targeted in the expectations, whereas some other countries in Asia were actually identified as having severe impacts. In addition, some countries identified in the study such as Brazil and Bolivia in South America, Russia and Saudi Arabia were not mentioned. As regards the critical phases, there was a match in identifying resource extraction, while the reference group did not expect refining and processing or manufacturing and assembly to be on the list. A possible explanation is that they implicitly included at least refining and processing in the resource extraction phase. However, recycling and disposal turned out to be less important in this study than expected by the reference group, which is probably the explanation for them expecting Africa to be a hot region. The conclusions from this comparison are that the results do not match exactly. The reason for the different outcomes can be either methodological or data shortcomings, giving an incorrect result, or an indication that some new knowledge can actually be gathered by our method.

Finally, it is interesting to note that our analysis brings the level of discussion of the social impacts in the product system one step further, by identifying impacts on the level of subcategories (as well as indicator levels if desired). This indicates that the methodology for S-LCA can actually provide new insights to stakeholders about social impacts in a product system.

There are uncertainties associated with the results presented in this paper. In parallel with environmental LCA, there are many types of uncertainties involved, related both to data and to methodological choices (c.f. Huijbregts 1998; Björklund 2002; Finnveden et al. 2009). In future, there is a need to identify and describe these uncertainties also for S-LCA.

5 Conclusions

This study shows that it is possible to conduct a simplified S-LCA, using the Guidelines for social LCA, on a generic complex product. While we encountered some challenges, for example in data collection, we were able to obtain results which revealed some hotspots, some hot countries and some hot issues, all indicating a risk of negative social impacts in the product system of a laptop.

The study identified workers and the local community as the stakeholders most at risk of negative social impacts, with social benefits/social security, working hours, and freedom of association as important issues or workers while the local

Table 14 Comparison between expected and identified social impacts

Aspect	Expected impacts	Impacts identified
Country/region	China, Africa	China, Brazil, other Asian and South-American countries
Phase	Resource extraction, recycling and disposal	Resource extraction, refining and processing, manufacturing and assembly
Stakeholder	Workers	Workers, local community
Subcategory	Not specified	See Table 12

community was mostly affected by access to immaterial resources, safe and healthy living conditions, community engagement, delocalisation and migration, cultural heritage, and respect for indigenous rights. The countries showing up as potentially important were Russia, Saudi Arabia, Thailand, and Brazil. These are generally less frequently mentioned in relation to ICT products, which may illustrate the added value of the life cycle perspective.

On comparing the expected and actual outcome of the study in order to analyse whether the results seemed reasonable, we noted some differences. This indicates that by making an S-LCA, new insights may be gained. It appears that knowledge of the social impacts in the product system can be brought one step further by identifying impacts on the level of subcategories (as well as indicator levels if desired). Thus, the methodology for S-LCA can possibly provide new insights to stakeholders about social impacts in a product system. In other words, the life cycle perspective and systematic approach may help users identify potentially important aspects that might otherwise have been neglected.

However, there are methodological issues that need further attention. One such is the impact pathways for the indicators in measuring real social impact, needing substantial improvement. The difficulty in finding data and the need for simplifications also indicates a need for further development of the methodology. These methodological shortcomings render the results from this case study subject to uncertainties.

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